AD-A069 962 ADVISORY GROUP FOR AEROSPACE RESEARCH AND DEVELOPMENT--ETC F/G 5/1
RESEARCH AND DEVELOPMENT ACTIVITIES IN ITALY IN THE FIELD OF AE--ETC(U)
MAR 79 L LAZZARINO

UNCLASSIFIED AGARD-R-675 NL

1 OF 1

AD
A069962

END
DATE
FILMED
7-79
DDC

AGARD-R-675

AGARD

ADVISORY GROUP FOR AEROSPACE RESEARCH & DEVELOPMENT

7 RUE ANCELLE 92200 NEUILLY SUR SEINE FRANCE

AGARD REPORT No. 675

Research and Development Activities in Italy in the Field of Aerospace Structures and Materials

NORTH ATLANTIC TREATY ORGANIZATION

DISTRIBUTION AND AVAILABILITY
ON BACK COVER

B783

4

AGARD

NATO OTAN

7 RUE ANCELLE · 92200 NEUILLY-SUR-SEINE

FRANCE

Telephone 745.08.10 · Telex 610176

DISTRIBUTION OF UNCLASSIFIED AGARD PUBLICATIONS

AGARD does NOT hold stocks of AGARD publications at the above address for general distribution. Initial distribution of AGARD publications is made to AGARD Member Nations through the following National Distribution Centres. Further copies are sometimes available from these Centres, but if not may be purchased in Microfiche or Photocopy form from the Purchase Agencies listed below.

NATIONAL DISTRIBUTION CENTRES

BELGIUM
Coordonnateur AGARD – VSL
Etat-Major de la Force Aérienne
Quartier Reine Elisabeth
Rue d'Evere, 1140 Bruxelles

CANADA
Defence Scientific Information Service
Department of National Defence
Ottawa, Ontario K1A OZ2

DENMARK
Danish Defence Research Board
Østerbrogades Kaserne
Copenhagen Ø

FRANCE
O.N.E.R.A. (Direction)
29 Avenue de la Division Leclerc
92 Châtillon sous Bagneux

GERMANY
Zentralstelle für Luft- und Raumfahrt-
dokumentation und -information
c/o Fachinformationszentrum Energie,
Physik, Mathematik GmbH
Kernforschungszentrum
7514 Eggenstein-Leopoldshafen 2

GREECE
Hellenic Air Force General Staff
Research and Development Directorate
Holargos, Athens, Greece

ICELAND
Director of Aviation
c/o Flugrad
Reykjavik

ITALY
Aeronautica Militare
Ufficio del Delegato Nazionale all'AGARD
3, Piazzale Adenauer
Roma/EUR

LUXEMBOURG
See Belgium

NETHERLANDS
Netherlands Delegation to AGARD
National Aerospace Laboratory, NLR
P.O. Box 126
Delft

NORWAY
Norwegian Defence Research Establishment
Main Library
P.O. Box 25
N-2007 Kjeller

PORTUGAL
Direcção do Serviço de Material
da Forca Aerea
Rua da Escola Politecnica 42
Lisboa
Attn: AGARD National Delegate

TURKEY
Department of Research and Development (ARGE)
Ministry of National Defence, Ankara

UNITED KINGDOM
Defence Research Information Centre
Station Square House
St. Mary Cray
Orpington, Kent BR5 3RE

UNITED STATES
National Aeronautics and Space Administration (NASA)
Langley Field, Virginia 23365
Attn: Report Distribution and Storage Unit

THE UNITED STATES NATIONAL DISTRIBUTION CENTRE (NASA) DOES NOT HOLD STOCKS OF AGARD PUBLICATIONS, AND APPLICATIONS FOR COPIES SHOULD BE MADE DIRECT TO THE NATIONAL TECHNICAL INFORMATION SERVICE (NTIS) AT THE ADDRESS BELOW.

PURCHASE AGENCIES

Microfiche or Photocopy
National Technical
Information Service (NTIS)
5285 Port Royal Road
Springfield
Virginia 22161, USA

Microfiche
Space Documentation Service
European Space Agency
10, rue Mario Nikis
75015 Paris, France

Microfiche
Technology Reports
Centre (DTI)
Station Square House
St. Mary Cray
Orpington, Kent BR5 3RF
England

Requests for microfiche or photocopies of AGARD documents should include the AGARD serial number, title, author or editor, and publication date. Requests to NTIS should include the NASA accession report number. Full bibliographical references and abstracts of AGARD publications are given in the following journals:

Scientific and Technical Aerospace Reports (STAR)
published by NASA Scientific and Technical
Information Facility
Post Office Box 8757
Baltimore/Washington International Airport
Maryland 21240, USA

Government Reports Announcements (GRA)
published by the National Technical
Information Services, Springfield
Virginia 22161, USA

Printed by Technical Editing and Reproduction Ltd
Harford House, 7–9 Charlotte St, London W1P 1HD

ISBN 92-835-1315-0

UNITED STATES DEPARTMENT OF COMMERCE
National Technical Information Service
5285 Port Royal Road
Springfield, Virginia 22161

Date 30 May 1979 NTIS Control # 150 177

TO: Defense Documentation Center - DDC/TC
Cameron Station
Alexandria, Virginia 22314

FROM: NTIS, Input Branch
5285 Port Royal Road
Springfield, Virginia 22161

AD A069962

Report # Agard - R - 675 ADA #

Title: "Research and Development Activities in Italy"

Subject report is [X] Standard Process [ ] STG report. STG - Special Technology Group. [ ] Computer Product. [ ] Follow up date ______.

[ ] The report will be accessioned by DDC. The form noting the ADA number is returned.

[ ] The report has been assigned the ADA number noted above and is returned to NTIS for processing.

[ ] DDC will not process the report. It is returned to NTIS.

Mag Tape Price ______

PC & MF Price ______ Source DODSD

Stock Quantity 4 Source Share ______

Comments: Bin - 783

______
Signature (for billing)

Copy when completed to
Finance Branch.

DOD Report Action Request
(Replaces NTIS-164 5-72)

Dottie Adams
processor

14 AGARD-R-675

NORTH ATLANTIC TREATY ORGANIZATION

ADVISORY GROUP FOR AEROSPACE RESEARCH AND DEVELOPMENT

(ORGANISATION DU TRAITE DE L'ATLANTIQUE NORD)

AGARD Report No.675

6 RESEARCH AND DEVELOPMENT ACTIVITIES IN ITALY IN THE FIELD OF AEROSPACE STRUCTURES AND MATERIALS

by

10 Professor L. Lazzarino
Universita degli Studi
Facolta di Ingegneria
Via Diotisalvi 2
56100 Pisa
Italie

11 Mar 79

12 29p.

Technical Address given at the 47th Meeting of the Structures and Materials Panel in Florence, Italy on 25 September 1978.

400 043 JOB

THE MISSION OF AGARD

The mission of AGARD is to bring together the leading personalities of the NATO nations in the fields of science and technology relating to aerospace for the following purposes:

– Exchanging of scientific and technical information;

– Continuously stimulating advances in the aerospace sciences relevant to strengthening the common defence posture;

– Improving the co-operation among member nations in aerospace research and development;

– Providing scientific and technical advice and assistance to the North Atlantic Military Committee in the field of aerospace research and development;

– Rendering scientific and technical assistance, as requested, to other NATO bodies and to member nations in connection with research and development problems in the aerospace field;

– Providing assistance to member nations for the purpose of increasing their scientific and technical potential;

– Recommending effective ways for the member nations to use their research and development capabilities for the common benefit of the NATO community.

The highest authority within AGARD is the National Delegates Board consisting of officially appointed senior representatives from each member nation. The mission of AGARD is carried out through the Panels which are composed of experts appointed by the National Delegates, the Consultant and Exchange Programme and the Aerospace Applications Studies Programme. The results of AGARD work are reported to the member nations and the NATO Authorities through the AGARD series of publications of which this is one.

Participation in AGARD activities is by invitation only and is normally limited to citizens of the NATO nations.

The content of this publication has been reproduced directly from material supplied by AGARD or the author.

Published March 1979

ISBN 92-835-1315-0

Printed by Technical Editing and Reproduction Ltd
Harford House, 7–9 Charlotte St, London, W1P 1HD

PREFACE

It is the aim of the AGARD Structures and Materials Panel to stimulate and improve cooperation and exchange of technical information among the NATO member nations with regard to the science and technology of aerospace structures and materials.

Of major importance in fulfilling this task are the bi-annual Meetings of the Structures and Materials Panel, which bring together the leading people of the member nations working in this field. Moreover, the presentations given during these meetings and the ensuing discussions become available to the whole scientific community as AGARD Publications.

It has become a custom that, during the opening session of a Structures and Materials Panel Meeting, the host nation gives a presentation describing their country's activities related to aerospace structures and materials.

The 47th Meeting of the Panel took place from 25–29 September 1978 in Florence, Italy and, at this Meeting, Professor L.Lazzarino of the University of Pisa had the difficult task of presenting in a limited time a concise but complete survey of the aerospace research and development activities in Italy. He succeeded so well in this task that the Structures and Materials Panel decided unanimously to publish Professor Lazzarino's presentation as an AGARD Report. It is hoped that this very interesting survey of current programmes in Italy may stimulate possible cooperation and exchange of information.

J.B. de JONGE
Chairman, Structures
and Materials Panel

CONTENTS

RESEARCH AND DEVELOPMENT ACTIVITIES IN ITALY IN THE FIELD OF AEROSPACE STRUCTURES AND MATERIALS

by
Lucio Lazzarino
Dean of the Faculty of Engineering
University of Pisa - Italy

SUMMARY

After a summary of the main programs of the Italian aerospace industries, a review is performed of Research and Development activities, prevalently aimed at supporting these programs in the field of aerospace materials and structures; also, autonomous research work developed by some Italian Universities in this field is indicated.

This review considers the activities concerned with metallic and non metallic aerospace materials, the fields of stress analysis, vibrations and aeroelasticity, fatigue and crack propagation and particularly interesting development work aimed at resolving design problems and at facilitating the introduction of new technologies. Also, the main facilities developed are indicated.

1. INTRODUCTION

The Research and Development activities in Italy in the field of aerospace structures and materials are developed mainly to support the programs of the aerospace industries; moreover some research contracts were stipulated by Universities, both with the C.N.R. (National Research Council) and with foreing research agencies.

The programs of Italian aerospace industries take into consideration both contributions to international military, civil aeronautical and space programs and autonomous industrial activities for obtaining new prototypes. The aerospace production and overhaul activities will be not considered here.

The majority of the research work is performed by industrial laboratories or results from cooperation between Universities, the C.N.R. and aerospace industries; moreover, Universities perform research work independently, mainly in theoretical and computational areas.

Particular development activities are performed mainly by aerospace industries to resolve design and technological problems.

The Research and Development activities of the Laboratories of the Aeronautica Militare (D.L.A.M.) are mainly devoted to making operative testing methods for the acceptance of aerospace materials and of the involved technological procedures.

A first group of Research and Development work is devoted to the study of aerospace materials and of the technological procedures to be applied.

A second group is devoted to the study of problems of aerospace structures in the fields of stress analysis, vibrations, aeroelasticity, fatigue and crack propagation.

A summary of the activities concerning particular development work for the solution of some design and technological problems and for the improvement of tests procedures will then be given.

The Research and Development acitivities in the field of aerospace materials and structures require the design and the construction of certain facilities, that will also be described briefly.

For a better understanding of the Research and Development activities above indicated a summary of the main programs of the Italian aerospace industries may be useful.

2. SUMMARY OF PROGRAMS OF ITALIAN AEROSPACE INDUSTRIES

2.1 Civil Aircraft

In the field of civil aircraft Aeritalia is developing cooperation with Boeing concerning the advanced commercial aircraft 767 program, for which an extension of many years is foreseen.

In addition to cooperation for preliminary studies and general design activities, for design calculation, construction and testing of certain aircraft parts and subsystems and the involved tooling and facilities, Aeritalia will be relied upon and therefore involved in the required Research and Development activities.

Aeritalia is also developing a new version of the G.222 aircraft for forest fire quenching, [1].

Partenavia [2], Rinaldo Piaggio S.p.A. and SIAI-Marchetti are engaged mainly in autonomous programs concerned with general aviation aircraft and economic problems involved.

The programs of "Costruzioni Aeronautiche Giovanni Agusta S.p.A." (Agusta) are concerned mainly with the development of various types of helicopters, both for civil, Fig. 1, and military use; consequently, research and development activities in the field of structures and materials are aiming at improving design and production of parts and subsystems of helicopters.

2.2 Military Aircraft

In the Tornado-MRCA international program, Aeritalia has the responsability of the variable geometry wing design, construction and testing and of research and flight test activities concerning flutter, also with external loads.

Aeritalia is also developing various new versions of the turboprop military transport aircraft G.222 [3] (Fig. 2) and the new AMX program.

Aeronautica Macchi is developing the new MB 339 trainer, Fig. 3, and has the responsability of design, construction, testing and development at the external main wing structures of G.222 and of the wing pilons of Tornado-MRCA aircraft; moreover, it contributes to the new AMX program. Rinaldo Piaggio has the responsability of design, construction, testing and development of the internal main wing structure of the G.222 aircraft.

Military and police versions of some types of helicopters are being developed by Agusta (Fig. 4) also in cooperation with SIAI Marchetti, Fig. 5,that is, moreover,developing military versions of certain general aviation aircraft.

2.3 Space Programs

Various Italian aerospace and avionics industries, led by the Compagnia Nazionale Aerospaziale, are engaged in the national experimental Sirio satellite program, under the supervision of the CNR-SAS, as well as in the new national launcher Alfa-program.

The C.R.A. (Centro Ricerche Aerospaziali of the Scuola di Ingegneria Aerospaziale of Rome University), within the framework of the well known "San Marco Project", with the active cooperation of Italian Air Force personnel, has designed, developed and put into orbit (by the C.R.A. launching team, acclaimed by NASA one of the best in the world)from the equatorial Italian Range (Malindi, Kenia) several S. Marco aeronomus satellites,whose main instrumentation (the so-called "balance") is based upon an original elasto-structural concept.

It should be pointed out that at the C.R.A., with the support of the Italian Air Force, a great complex of experimental means for tests on aerospace structures has been realized.

In particular the C.R.A. has developed original techniques for the measurement of thermal fluxes corresponding to the aerodynamic heating over supersonic and hypersonic speed aircraft or over space-ships during the re-entry phase in the terrestrial atmosphere.

Furthermore, the C.R.A. experimental equipment includes big dimensions vibrators, satellite structure balancing machines and a simulator for cosmic vacuum effects and solar radiation tests over satellites, which has been the first to enter into operation in western Europe.

Aeritalia is responsable for the primary and secondary structures of the Spacelab (Fig. 6) and, in cooperation with Microtecnica, for the Spacelab Thermal Control System [4]. This task required remarkable Research and Development activity, also in the field of aerospace materials and structures, and in that of involved sophisticated technological procedures.

Aeritalia also partecipates in O.T.S. international programs (control system and satellite structure),E.C.S.(responsability for design and manufacturing of satellite structure), MAROTS (as well as O.T.S.) and Ariane (design and production of the Capsule Technologique).

Selenia is remarkably active in the design and construction of Satellite antennas, to be used in Intelsat IV, O.T.S., Sirio, Meteosat, Cos B, Intelsat V, ECS, HSat, Sirio 2, Aerosat-ESA and 20/30 GHz ESA programs [5,6].

Therefore adequate Research and Development work is required, particularly for the application of new materials, to the solution of the complex antennas problems.

3. RESEARCH AND DEVELOPMENT WORK CONCERNED WITH AEROSPACE MATERIALS AND TECHNOLOGIES

3.1 Metallic Materials and Respective Technologies

The design and the construction of the Spacelab primary and secondary structures required the development by Aeritalia of particular equipment for the application of the Tungsten Inert Gas welding system, for obtaining constant high quality welding in large structures such as those of the Spacelab, and to adequately control the welds obtained.

The Centro Ricerche FIAT is developing research work on surface treatments by high power Laser on Nickel superalloys and on heat treatment powder metallurgy Nickel-base superalloys. The results obtained up to now, through this research work, and the methods and procedures used will be explained in detail later in a paper presented at this meeting.

FIAT Aviazione is developing experimental research work on:

- High temperature creep under fatigue loading of PK 24 and IN 100;
- Slurry techniques to obtain protection against corrosion through various coatings (a patent concerned with aluminium coating of metallic elements was obtained);
- Cooperative research about high temperature behaviour of NIMOCAST 739;
- Ion implantation and Laser applications to obtain improvement of surface chracteristics of metallic materials;
- Development of high temperature sintering procedures (Astroloy);
- NDI of materials applying small angle neutron scattering [7].

The University of Bologna (Istituto di Metallurgia) began, under the sponsorship of the D.L.A.M., research work on the behaviour at high temperatures of Ni-Alumina composite

materials obtained through electrocodeposition. This work was then continued autonomously and interesting results were obtained; the characteristics of these composite materials were investigated at temperatures up to 1100 °C [8,9]. Now this research has been extendend to Ni-Fe-Alumina, Ni-Cr-Alumina and Ni-Bo systems.

Development work for the technology required for the construction of sophisticated satellite antennas, support frameworks, reflectors and polarizers was carried out by Selenia for the application of several particular kinds of Steel, Aluminium and Magnesium alloys and Invar to the construction of such structural elements.

Agusta has recently developed experimental research work for the determination of the influence of the forming and casting procedures and of metallurgical defects in aluminium cast alloys on their fatigue behaviour [10].

The Istituto Sperimentale dei Metalli Leggeri is devoloping research work, sponsored by the D.L.A.M., to obtain a comparison between the characteristics of Zergal 3 and Zergal 4 forged Aluminium alloys and those of Alcoa X 7050. To improve the characteristics of alloys of this type new compositions are now being subjected to investigation.

Moreover, research work is being carried out at ISML to obtain, through new thermomechanic treatments (TTMF, TTMI) of new Aluminium alloys of the 7000 series, improvement of their maximum strength and fatigue behaviour.

3.2 Non-Metallic Materials, Organic Bonding and Respective Technologies

The possible applications of various reinforced organic fiber materials, both to aircraft and spacecraft structures, attracted the attention of certain Italian aerospace industries. Therefore a remarkable effort, mainly consisting in development work, was recently made by certain industries, sometimes in cooperation with the C.N.R. and Universities.

Aeritalia is now developing an extensive program for the application of carbon fiber reinforced polymerized resin to the construction of movable airplane surfaces (ailerons, flaps, elevators, rudders, spoilers, tabs, etc.) also for large aircraft. After preliminary research to obtain a mathematical model of the behaviour of such structures prototypes structures were designed, calculated and built; certain components are now being subjected to fatigue testing. Moreover, a framework to support a space telescope to be used upon a satellite was obtained by bonding structural elements built in carbon reinforced resin.

SIAI Marchetti is carrying out the development work required to obtain an increasing application of bonding procedures to the construction of wide wing honeycomb panels also of the main wing structure of general aviation aircraft. Bonded structural elements are also adopted for other structures of such aircraft to obtain lighter and cheaper solutions.

The Research and Development work going on aims at obtaining the extensive substitution of the metal skins of honeycomb panels with sheets of reinforced resin.

Agusta and Elicotteri Meridionali are developing a Research and Development program for the extensive application of composite materials to helicopter structures, also with the aim of obtaining remarkable noise reduction because of the good damping characteristics of such materials.

Research work carried out jointly by the Istituto di Tecnologia Aerospaziale of the University of Roma and Selenia, under the sponsorship of the CNR-SAS, is now under way to analyze the possible applications of various composite materials to the construction of directional antennas for telecomunication satellites using frequencies between 10 and 30, GHz; this research requires special test facilities [11].

Selenia also carried out remarkable development activity for the application of glass, carbon and boron fiber materials and bonding technologies in the construction of satellite antennas [12].

Bonding centres to obtain the safe industrial bonding of aircraft structures were recently developed by Aeritalia at Pomigliano, by the SIAI Marchetti at Sesto Calende and Agusta at Cascina Costa.

4. AEROSPACE STRUCTURAL PROBLEMS

4.1 Stress Analysis of Aerospace Structures

Research into the stress analysis of aircraft and spacecraft structures was performed both with general methods and with reference to special applications, applying theoretical, computational and experimental procedures.

Such research activity has been considerably developed in Italy over the past decades, obtaining remarkable results, generally reported in reviews and proceedings of conferences, academies and scientific and technical societies, particularly in the review entitled "L'Aerotecnica, Missili e Spazio".

An extensive historical and critical analysis of such long lasting research cannot be given here; the more recent results are explained in detail in the papers indicated in the enclosed reference list,(from [13] to [24]).

Summarizing, in the field of theoretical methods, Prof. Cicala, in a very remarkable recent paper, has further expanded his asymptotic formulation of linear shell theory, developing a fully rational approach for obtaining the relevant parametric expansions, [13].

Other contributions in this field are the application of variational techniques to the non-linear behaviour of aerospace structural panels [14] and to the development of a

new method in eigensolution search [15].

Remarkable theoretical research on structural thermal problems, particularly concerned with anisotropic aerospace structures, was carried out by the Centro Ricerche Aerospaziali of the University of Roma, solving the equations of heat conduction in anisotropic bodies in an original way [16,17,18].

In the computational field, several computer programs have been developed in the Universities to solve certain kinds of problems unsuitable for treatment through general purpose computer programs.

Amongst them we can quote two finite element approaches to obtain the Stress Intensity Factor both in bidimensional and tridimensional cases [19,20] and computer programs to determine elastic stress states among contacting bodies, in particular in pin joints [21].

Other contributions concern the application of finite element method to the classic problems of semimonocoque aircraft structures [22,23].

One of the aims of computational research work is the reduction of the cost and the time required to obtain the necessary quantitative results by applying the various proposed mathematical model and finite element methods [24,25].

General purpose computer programs are extensively used by Italian aerospace industries in solving design problems. Fig. 7 gives an account of computerized structural analysis in use at Aeronautica Macchi.

For complex structures computer results are generally substantiated by strain measurements.

Typical examples are the work on the hub of the main of the Agusta A 109 A helicopter [26] and the calculations carried-out by Aeritalia on the diffusion panel (Fig. 8), which constitutes the rotation hinge of the outer half-wing of the Tornado-MRCA aircraft.

Other original computational programs or subroutines have been developed by various industries to face particular design problems.

Selenia developed some computational programs for the study of the thermoelastic problems of satellite antennas, particularly with reference to the deformation allowed by telecommunication requirements [27,28,29,30].

4.2 Vibrations and Aeroelasticity

As for stress analysis of aircraft and spacecraft structures, remarkable research activity has been going on into vibrations and aeroelastic phenomena in aircraft and spacecraft during the past decades in Italy, mainly in the Universities.

The results of this activity can generally be found in reviews and proceedings, and particularly in the review "L'Aerotecnica Missili e Spazio".

The more recent papers dealing with this research field are indicated in the enclosed reference list (from [31] to [42]), and can be summarized as followed

The dynamic behaviour and the response to random excitation of thin walled stiffened aircraft and spacecraft structures has been studied by the University of Pisa and by the Technical University of Milano (Politecnico), particularly in the acoustic range because of the remarkable importance of acoustic fatigue in modern aircraft and spacecraft structures.

Computational methods which take into account both bending-torsion displacements and distorsion of the stringer cross-section, [31], or those based on finite strip elements [32], were developed.

The response of stiffened panels to acoustic excitation, expressed both in displacement and stress terms, was obtained with a procedure based on modal analysis technique.

Tests were conducted [31,33,34,35,36] to obtain the frequencies and the mode shapes of the response. A comparison between the theoretical and experimental results show satisfactory agreement.

In the field of aeroelasticity a new formulation of the flutter equations allowing efficient solutions both by a continuation and a direct method, [37], and extremely effective methods for solving divergence and flutter eigenproblems, [38,39], have been developed by the Istituto di Ingegneria Aerospaziale of the Technical University of Milano (Politecnico).

The Istituto di Tecnologie Aerospaziali of the University of Rome has carried out research work on the problem of computing unsteady aerodynamic forces in flutter problems; the result obtained up to now will be presented in this meeting [40].

These original results, obtained thanks to an Italian Air Force Contract, are of a general nature and are presented in operational form.

The Centro Ricerche Aerospaziali of the University of Rome is developing a theoretical and experimental research program about damping in spacecraft structures, using the St.Marco satellite data [41].

Aeroelastic phenomena require continuous improvement of calculation methods to allow the designer to face design problems effectively, in particular in the case of combat aircraft with different types of external stores.

Aeritalia, within the Tornado-MRCA program, has the primary responsability of research and experimentation of flutter in flight also with external stores, (Fig. 9).

Aeronautica Macchi has developed a mathematical model of a vibrating aircraft to investigate the effect of various mass distribution and of suitably dimensioned recoil dampers on the firing dispersion of 30mm guns carried under the wings. The model was checked by ground vibration tests and the results so obtained were confirmed by ground firing tests (Fig. 10).

Under the sponsorship of the CNR-SAS a cooperative research team, made up of staff from the Universities of Genoa, Pisa, Rome and Naples, as well as from Selenia and Aeritalia, has developed theoretical research work on the attitude control of telecommunication satellites bearing antennas requiring very high directivity.

The Istituto di Tecnologia Aerospaziale of the University of Rome was responsable for

the part of this research dealing with the elastodynamic phenomena that may influence the attitude of such a satellite [42,43,44,45].

After accurate theoretical analysis two calculation programs [46] were developed and applied to evaluate the above mentioned phenomena.

Furthermore the Istituto di Tecnologie Aerospaziali of the University of Rome studied the mathematical structural model of the OTS satellite, in cooperation with Selenia, and of the Sirio satellite in cooperation with the C.N.A.

4.3 Fatigue and Crack Propagation

Considerable attention has been paid in Italy to fatigue and crack propagation in aircraft and spacecraft structures, both by industries and Universities.

Cooperative theoretical and experimental research sponsored by the CNR-SAS has been carried out by a team made up of a staff from the Technical Universities of Milan and Turin, the University of Pisa and Aeritalia.

The items of this research are summarized in Fig. 11.

The main results obtained so far are summarized in the paper entitled "Fracture Mechanics Approaches in the Design of Aerospace Vehicles", [47].

In particular, extensive experiments are being carried out to assess the fracture behaviour of several Aluminium alloys,[48], and to evaluate on a common basis the most popular methods for ductile fracture mechanics, Fig. 12. An original model for ductile fracture was developed, implemented throug finite element analyses and evaluated by test data, [49,50], Fig. 13.

Classification of the crack growth behaviour of different stiffened and riveted panel configurations was drawn up on the basis of systematic experimental data,[51,52,53,54]. The test data obtained show the remarkable influence of stiffness between the joined elements on the crack growth behaviour of the various types of panel investigated, Fig. 14. Further investigation on this topic is aimed at obtaining an applicable analysis of these influences.

Theoretical and experimental investigation into the reliability of various crack growth computation methods is being carried out following the rationale shown in Fig. 15.

An extensive investigation into the impact of the damage tolerant structure requirements on the minimum weight configuration of stiffened structures is being carried-out with of an optimization computer program based on the penalty function and mathematical programming methods [55,56].

The University of Pisa is taking part in the AGARD SMP Program on "Critically Loaded Hole Technology" carrying out Falstaff spectrum fatigue tests on behalf of Italy,[57].

The University of Pisa recently concluded theoretical and experimental research sponsored by the European Research Office of the U.S. Army into the fatigue crack propagation in stiffened panels [58] and now is carrying on work (sponsored by both the U.S. Army and the U.S. Air Force through the European Research Office) on the fatigue crack growth under variable amplitude loading in built-up structures. To develop this research activity the University of Pisa set up a facility system to perform fatigue tests, which allows a wide variety of loading programs and the collection of much experimental data (Fig. 16). Under the sponsorship of the CNEN the University of Pisa devised an experimental research program on low cycle high temperature fatigue [59,60].

Aeritalia is developing a three-years research program on the fatigue behaviour of structures in the G. 222 aircraft; this program includes the systematic collection and elaboration of flight data and extensive laboratory testing (Fig. 17).

Aeronautica Macchi is collecting and elaborating statistical data on fatigue behaviour of typical structures of the MB 326 aircraft in greatly differing flight conditions, in 12 different countries, over a period of 20 years, in which about one million flight hours were recorded.

Laboratory fatigue tests for 120.000 simulated flight hours were carried out. A comparison was made between test results and the theoretically evaluated crack propagation in certain structural elements,[61,62,63].

5. PARTICULAR STRUCTURAL DEVELOPMENT ACTIVITIES

To face particular design problems development activities were performed, mainly by aerospace industries, through experimental investigation that required the design and the setting up of special test facilities and devices.

Some of them will be briefly indicated here.

Aeritalia set up particular facilities to submit the whole structure of the Spacelab, with the more relevant connected subsystems, to static and fatigue test (Fig. 18).

Previously, vibration systems, environmental chambers and acceleration systems were set up to perform development activities required by satellite design.

Agusta developed particular facilities for fatigue testing of the main helicopter structural elements adequately simultating the heavier combinations of foreseen flight conditions [64] (Fig. 19). Aeronautica Macchi set up a facility to simulate the bird impact on aircraft (Fig. 20) and landing gear drop test facilities to improve the shock-absorbing system.

Rinaldo Piaggio developed a fail safe fuselage air tank test facilities to check structural solutions aiming at preventing explosive decompression due to unstable propagation of cracks which may occur during the aircraft's life. Interesting results were obtained with the use of these facilities.

The Technical University (Politecnico) of Torino carried out development activity to obtain extruded solutions for wing and aileron structures for various types of aircraft.

The extruded elements can be chemically milled to obtain adequate variation of their thickness. Experiments were performed and others will soon be completed [65].

6. CONSIDERATIONS ON THE AVAILABLE RESEARCH AND DEVELOPMENT CAPACITIES AND FACILITIES IN ITALY IN THE FIELD OF AEROSPACE STRUCTURES AND MATERIALS

The main programs briefly summarized above of the Italian aerospace industries indicate clearly their more relevant interests in the general field of aerospace structures and materials.

From the foregoing synthetic review of Research and Development activities, both in aerospace industries and Universities, it is possible to obtain general information about the capabilities and facilities available in the field indicated above.

In the past decades, notwithstanding the heavy economic and financial difficulties that troubled the Italian aerospace industries and the well known general University crisis, a remarkable effort has been made to reach a good scientific and technical level both in industries and Universities. Modern computational programs were extensively acquired and then originally developed to face particular problems and to make their use cheaper. Cooperation between Italian aerospace industries and Universities and foreign industries and research agencies has improved and this also produced an improvement in the capabilities of the aerospace people and therefore of autonomously designed aircraft and spacecraft and of the autonomous underdeveloped university research activity.

The Research and Development facilities in the field of aerospace structures were developed, nevertheless following too strictly and sometimes inadequately the few aerospace programs capable of surviving. This inadequacy was particularly heavy in the field of new aerospace materials,the majority of activities in this field being devoted to development with a view to particular applications.

I hope this review has provided sufficient coverage of Italian capacities and interest in the general field of aerospace structures and materials and contributed to assisting this Panel in its objective of encouraging and facilitating cooperation between the larger and smaller nations.

REFERENCES

1.	Anon. Aeritalia	G 222 antincendio.
2.	Anon. Partenavia	Costruzioni Aeronautiche.
3.	Anon. Aeritalia	G 222 multipurpose transport,1978.
4.	Anon. Aeritalia	Space sector,1977.
5.	Anon. Selenia	Space activities.
6.	Anon. Selenia	Capabilities in satellite antennas.
7.	Pizzi	Application of Small Angle Neutron Scattering to NDI of Material and Manufactured Components. AGARD - Conference Proceeding n.234 Non Destructive Ispection Relationship to Aircraft Design and Materials.
8.	Paolombarini ed altri	Ossidazione a 900°- 1110°C di un composito Ni - Allumina ottenuto mediante elettrocodeposizione. Metallurgia Italiana, 1978.
9.	Gauzzi ed altri	Caratterizzazione di leghe composte Ni - Allumina ottenute per elettrocodeposizione. Galvanotecnica,1978.
10.	Hotz Simioni Wagner	Influenza di difetti metallurgici sul comportamento a fatica di leghe leggere fuse tipo AZ91C ed Avior B. Convegno di studi sulla fatica nelle strutture aerospaziali, Torino,1978.
11.	Balis Crema Marchetti Peroni	Misure sperimentali di caratteristiche dinamiche di composti. Istituto di Tecnologia Aerospaziale - Università di Roma,1978.
12.	Del Prete	GRP e CFRP, due tecnologie richieste dal progresso ma direttamente limitanti del progetto.Selenia.
13.	Cicala	Linear Shell Theory, an Asymptotic Approach. Ed. Levrotto & Bella, Torino,1978.
14.	Puccinelli	Programmed Ritz Method Application of Variational Techniques to non Linear Problems in Panels Mechanics. L'Aerotecnica Missili e Spazio,1977.
15.	Antona	A Perturbation to Several Eigen Value - Eigen Function Problem in "Problemi attuali di meccanica teorica ed applicata", Atti del Convegno Internazionale a ricordo di Modesto Panetti, Accademia delle Scienze di Torino,1977.
16.	Broglio	Thermal Re-Entry Problems of Anisotropic Structures. (9th ICAS Symposium).

17.	Broglio	Heat Conduction Problems in Anisotropic Bodies With Properties Depending Upon Temperature. (10th ICAS Symposium).
18.	Arduini Sgubini Ulivieri	Solutions of Heat Conductive Problems With Radiative Boundary Conditions on a Continous Scheme. Atti C.R.A., 43-44.
19.	Fontana Mantegazza	Calcolo del fattore di intensità degli sforzi in problemi bi e tridimensionali. Procedimento col Metodo degli Elementi Finiti - Prestampa n.5,IV°Congresso Nazionale A.I.D.A.A.,Milano,1977.
20.	Cella Lanciotti Perucchio	Analisi di problemi bi e tridimensionali di Meccanica della Frattura con elementi finiti tridimensionali. AIA 78.2 - Istituto di Aeronautica - Università di Pisa,1978.
21.	Cardani Mantegazza	Analisi per elementi finiti di problemi di contatto fra corpi elastici - Prestampa n.10,IV°Congresso Nazionale A.I.D.A.A., Milano,1977.
22.	Puccinelli	A Method of Solution for Multiple-Cell Semi-Monocoque Structures. L'Aerotecnica Missili e Spazio,1977.
23.	Mantegazza	Analysis of Semimonocoque Beam Sections by the Displacement Method. L'Aerotecnica Missili e Spazio,1977.
24.	Carmignani	MAPIST: ur programma, basato sul metodo degli elementi finiti, per la determinazione dello stato di sollecitazione statica e della distribuzione stazionaria di temperatura in corpi con comportamento lineare. Editrice Tecnico Scientifica,Pisa,1976.
25.	Carmignani De Paulis Lami	MAVIS: un programma, basato sul metodo degli elementi finiti, per la determinazione dello stato di sollecitazione in corpi con comportamento visco-plastico sottoposti a carichi variabili. Istituto di Impianti Nucleari,Pisa,1978.
26.	Russo ed altri	Verifica analitica del mozzo rotore principale dell'elicottero A 109 A. Atti del I°Congresso A.I.F.A.,Torino,1978.
27.	Perrotta	System Design, Performance and Test Philosophy of the Mechanically Despun Antenna Mounted on Board the SIRIO Satellite for the 12-18 GHz Experiment. XVI°Convegno sullo Spazio,Roma, 1976.
28.	Cremona	Stabilità di forma come requisito fondamentale del progetto strutturale di antenne ad alta direttività per impieghi spaziali. XVII°Convegno sullo Spazio,Roma,1977.
29.	Cremona	Considerazioni in margine al progetto termostrutturale delle antenne METEOSAT,OTS,SIRIO. XVI°Convegno sullo Spazio, Roma, 1976.
30.	Di Cunzo Nobili	Thermal Distorsion Analysis of SHF Antenna Reflector. Preliminary Phase, Selenia SIRIO/RT-141.
31.	Cavallini Salvetti	Theoretical and Experimental Research on Vibrations of Thin Walled Stiffened Structures. n.74-16, 9th ICAS Congress Haifa, 1974.
32.	Borri Mantegazza Merlini	Stiffened Panels Analysis by Finite Strip Method. L'Aerotecnica Missili e Spazio,1978.
33.	Cavallini Barsotti	Metodi sperimentali per la determinazione del comportamento dinamico di strutture in parete sottile irrigidite. L'Aerotecnica Missili e Spazio,1974.
34.	Merlini Salvioni	Oscillazioni proprie di un pannello irrigidito, rilievo sperimentale e analisi alle strisce finite - Prestampa n.7,IV° Congresso A.I.D.A.A.,Milano,1977.
35.	Cavallini Lanciotti	Sulla risposta di pannelli irrigiditi ad un campo di forze eccitatrici random. L'Aerotecnica Missili e Spazio,1976.
36.	Borri Cavallini	Acoustic Fatigue Assessment in Aerospace Vehicles. 11th Congress ICAS,Lisboa,1978.
37.	Cardani Mantegazza	Continuation and Direct Solution of the Flutter Equation. Computer & Structures,Vol.8,n.2,1978.
38.	Borri Mantegazza	Efficient Solution of Quadratic Eigenproblems Arising in Dynamic Analysis of Structures. Comp. Methods in Appl.Mech. and Eng.,Vol.12,1977.
39.	Mantegazza	Derivatives of Eigenvalues and Eigenvectors in Linear Quadratic Divergence and Flutter Eigenproblems. To be Published in AIAA Journal.
40.	Santini	A General Computing Program for the Calculation of the Aerodynamic Generalized Forces. AGARD 47th Meeting, Florence,1978.
41.	Arduini	Structural Damping in S.Marco Spacecraft. AGARD. Structure and Material Panel,Aalborg,1978.

42. G.L.I.S. — Sottogruppo Controllo d'Assetto Satelliti - Studio del controllo di assetto di un veicolo spaziale per telecomunicazioni,con antenne ad altissima direttività,Roma,1978.

43. Santini — Stability of Flexible Spacecraft. Acta Astronautica,Vol.3,1976.

44. Santini, Barboni, Balis Crema, Marchetti — Modello dinamico per lo studio della precisione di puntamento di un satellite stabilizzato a tre assi con controllo gerarchico. G.L.I.S. - SCAS,Vol.IV,Roma,1977.

45. Balis Crema, Barboni, Marchetti, Santini — Influenza delle appendici flessibili sul controllo a getto dei satelliti. G.L.I.S. - SCAS,Vol.IV,Roma,1977.

46. Balis Crema, Marchetti — Programmi di calcolo per il modello dinamico di un satellite a tre assi con controllo gerarchico. G.L.I.S. - SCAS,Vol.IV, Roma,1977.

47. Antona, Giavotto, Salvetti, Vallerani — Fracture Mechanics Approaches in the Design of Aerospace Vehicles. Paper Presented at the 11th ICAS Congress,Lisboa,1978.

48. Frediani — Ductile Fracture Mechanics Assessment of 2219-T851, 2024-T3 and 7075-T6 Aluminium Alloys. Paper Presented a the I° AIFA Congress,Torino,1978.

49. Giavotto — Crack Propagation in Ductile Materials. Paper Presented to EUROMECH 91,Varsavia,1977 - G.L.I.S. "Ricerca sulla meccanica della frattura in strutture spaziali pressurizzate e soggette a fatica acustica",3ª Rel.

50. Caprile, Lanz — Contributo all'interpretazione degli effetti tridimensionali nella frattura duttile - Prestampa n.8,IV° Congresso Nazionale A.I.D.A.A.,Milano,1977.

51. Salvetti — On the Behaviour of Cracked Riveted Stiffened Panels Undergoing Constant Amplitude Fatigue Loading. Proc. of the V°Int. Conference on Experimental Stress Analysis. P. n.21,CISM,Udine,1974.

52. Salvetti, Frediani, Grassi — Theoretical and Experimental Research on the Fatigue Behaviour of Cracked Stiffened Panels - Final Technical Report - European Research Office U.S. Army Contract n.DAJA 37-73-C-2821.

53. Salvetti, Del Puglia — Fatigue Crack Propagation in Stiffened Panels. The VIII° Congress of the Int. Council of the Aeronautica Sciences. p.n.72-40,Amsterdam,1972.

54. Salvetti — Fatigue Behaviour of Cracked Stiffened Panels - AGARD CP n.121. Structures and Material Panel, London,1976.

55. Cavallini, Salvetti — Minimum Weight Design of Stiffened Panels With Damage Tolerance and Buckling Constraint - Prestampa n.32,IV° Congresso Nazionale A.I.D.A.A.,Milano,1977.

56. Salvetti — On the Damage-Tolerance Design of Aircraft Structures - Prestampa n.5. AIFA Congress,Torino,Febbraio 1978.

57. Cavallini, Salvetti — Falstaff Spectrum Fatigue Test on Center Notched Specimens Performed at Institute of Aeronautics of Pisa University - Istituto di Aeronautica - Università di Pisa,1977.

58. Salvetti, Frediani, Grassi — Fatigue Behaviour of Stringers in Stiffened Panels - U.S.Army European Research Office. Contract n.DA-ERO-124-74G0042,1976.

59. Del Puglia, Manfredi, Tomassetti — High Temperature Low Cycle Fatigue Experiments on AISI 304 Stainless Steel Tubular Structures. Seventh Congress on Material Testing, Budapest,1978.

60. Salvetti, Casarosa — Recenti attività di ricerca dell'Istituto di Aeronautica dell'Università di Pisa nel campo della fatica delle strutture. L'Aerotecnica Missili e Spazio n.4,1973.

61. De Otto — Comparative Experimental Observations and Theoretical Analysis of the Propagation of Fatigue Cracks - AGARD CP n.221 - Structures and Material Panel,London,1976.

62. De Otto — Criteri generali del progetto a fatica e successivo controllo della vita dei velivoli presso l'Aeronautica Macchi - Preprint n.3, AIFA Congress,Torino,Febbraio 1978.

63. De Otto — Studio della propagazione della cricca sulla guida flap di un velivolo da trasporto. Preprint n.16,Torino,Febbraio 1978.

64. Pisso — Qualificazione a fatica dell'elicottero civile Agusta A 109 A. Convegno di Studi sulla Fatica nelle Strutture Aerospaziali, Torino,1978.

65. Romeo — Realizzazione per estrusione di strutture aeronautiche.Ricerca su struttura alare estrusa.IV°Congresso Nazionale A.I.D.A.,Milano 1977.

Fig. 1 - Agusta A 109 Civil Helicopter.

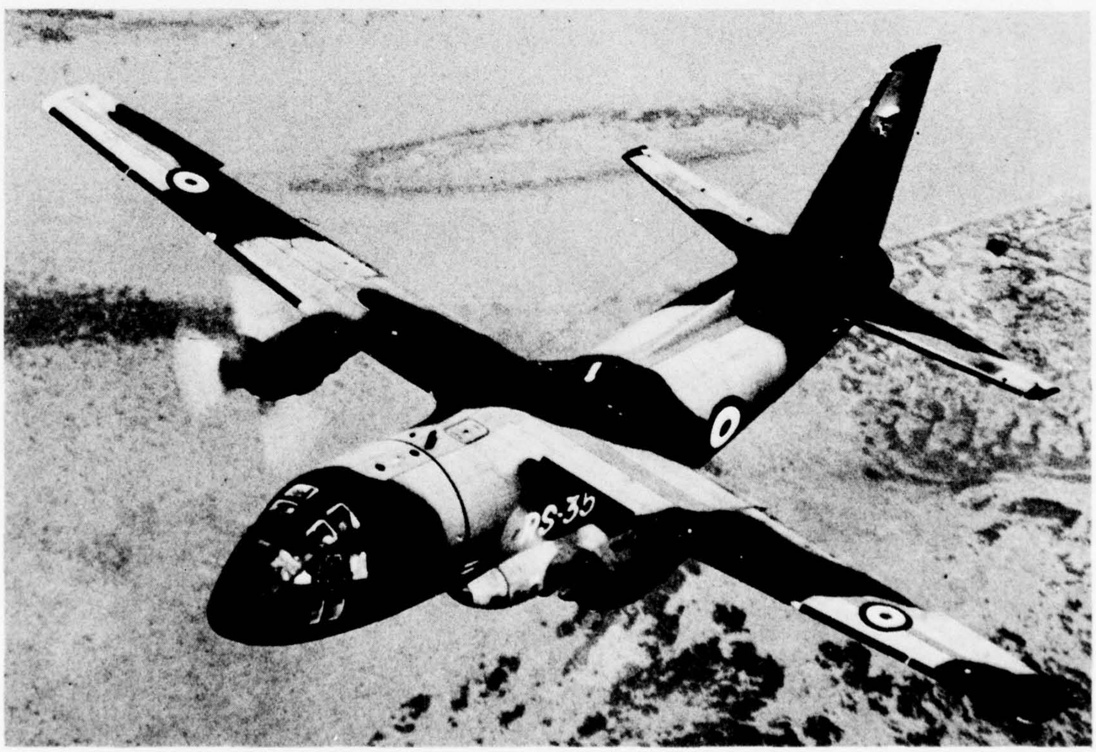


Fig. 2 - New military version of the G. 222 aircraft.

Fig. 3 - Aeronautica Macchi MB.339 trainer.

Fig. 4 - Military version of Agusta A 109 helicopter.

Fig. 5 - Agusta-SIAI Chinook CH 47 helicopter.

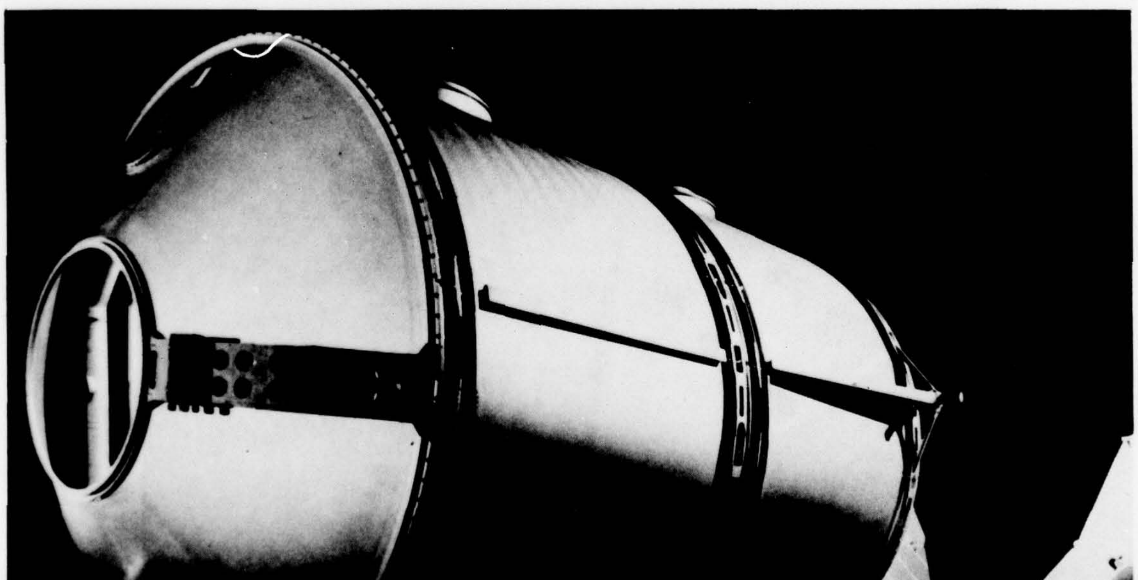


Fig. 6 - Spacelab primary structure.

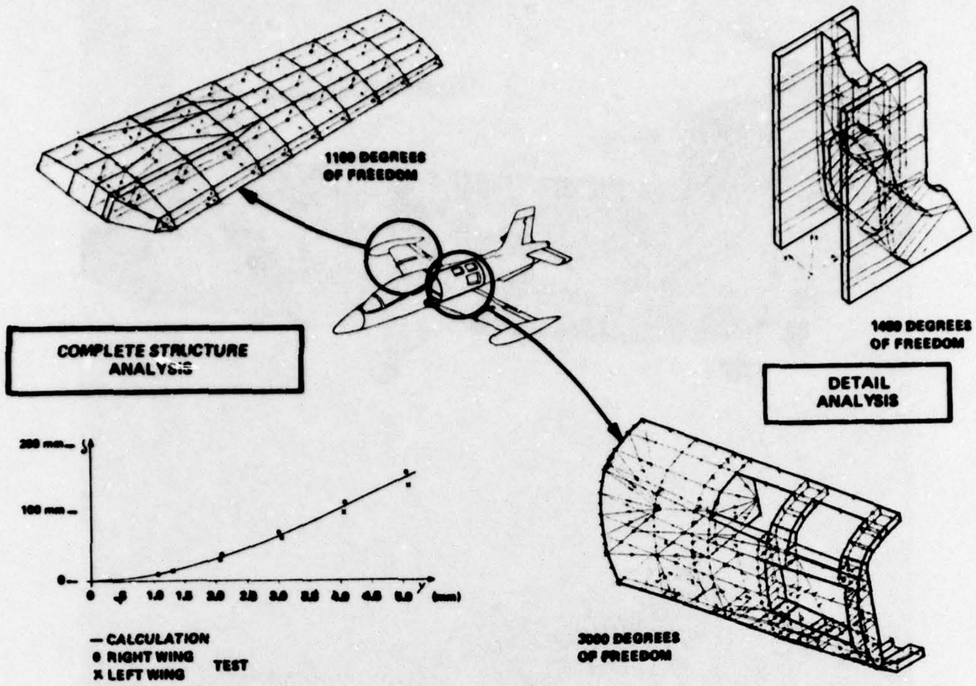


Fig. 7 - MB. 339 aircraft-stress analysis.

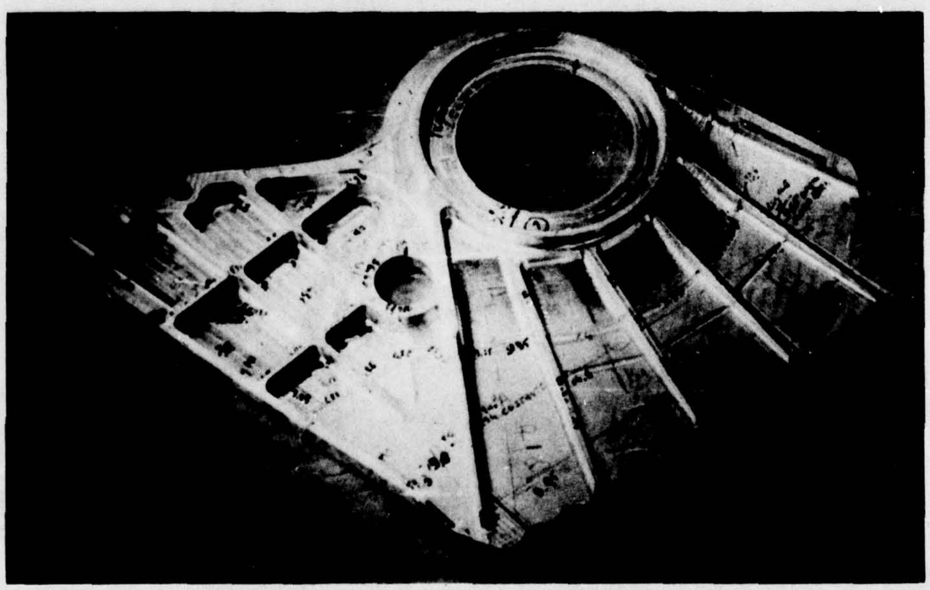


Fig. 8 - Tornado MRCA diffusion wing panel.

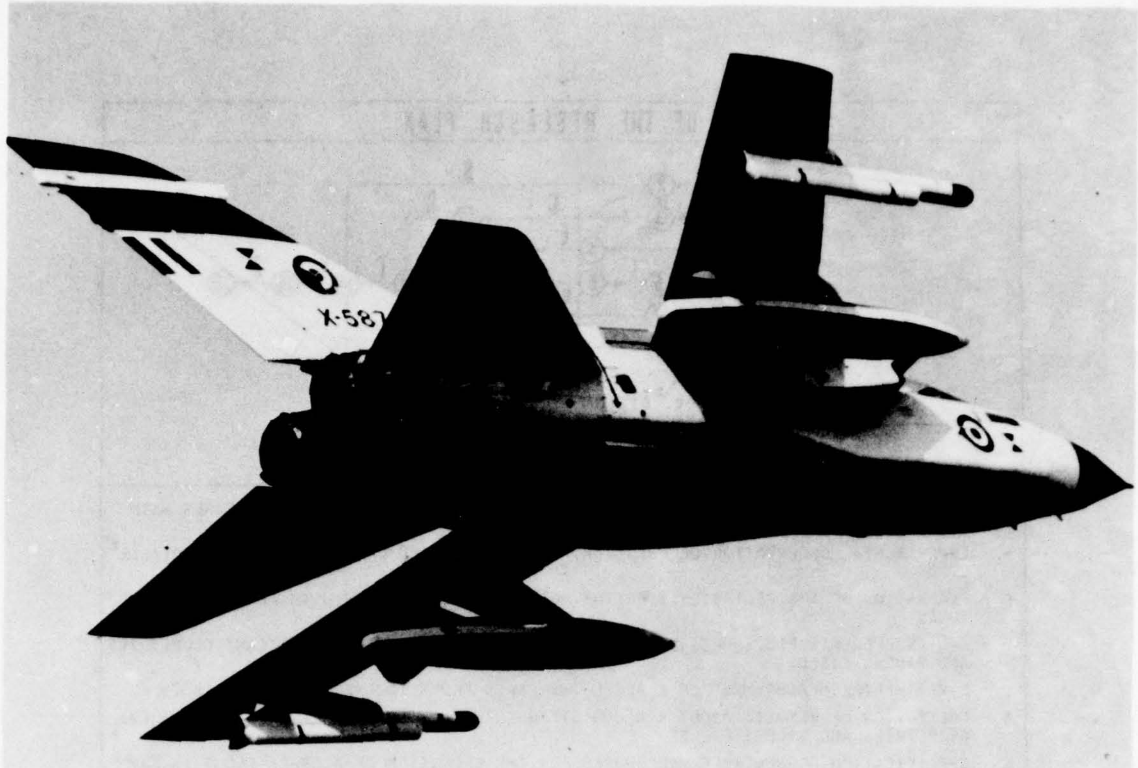


Fig. 9 - Tornado MRCA aircraft with external loads for flutter tests.

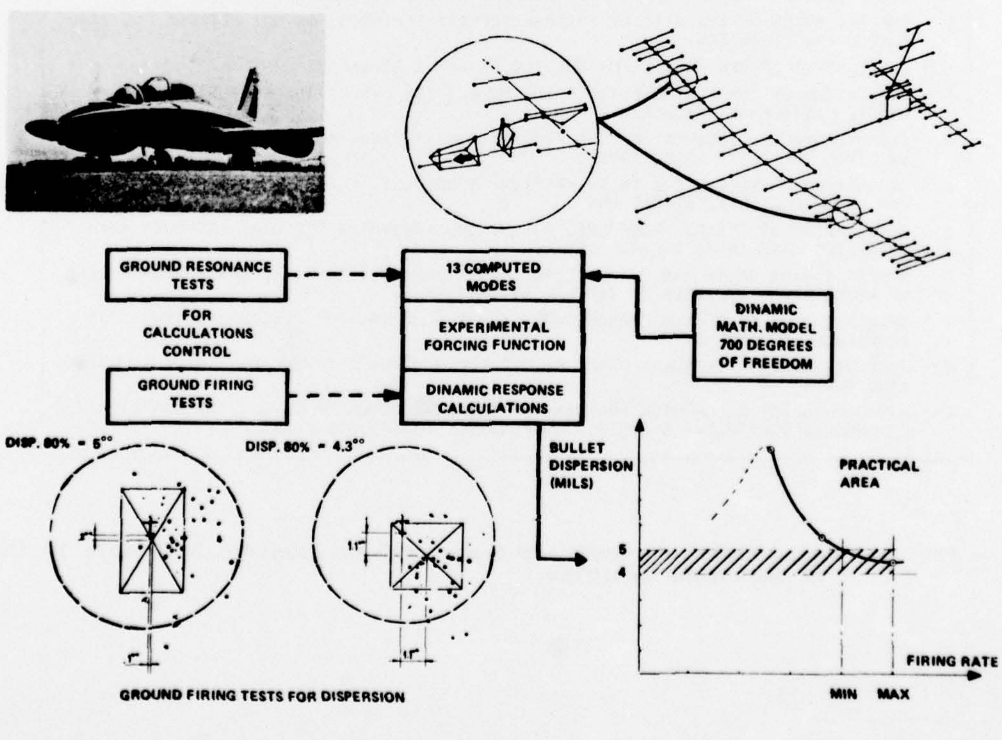
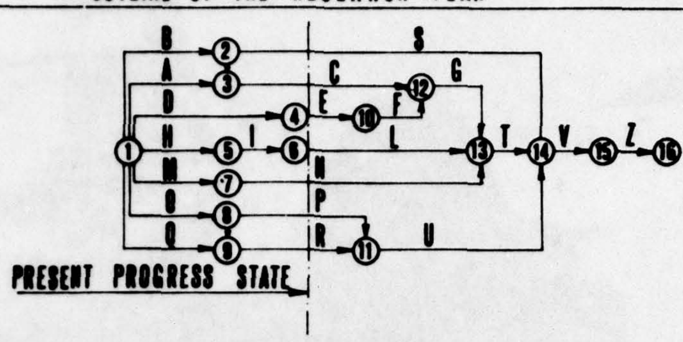


Fig. 10 - MB-339 30 mm. underwing gun pod dinamic structural behaviour.

OUTLINE OF THE RESEARCH PLAN



A - EXPERIMENTAL MEASUREMENTS OF CRACK GROWTH FOR TYPICAL AEROSPACE MATERIALS WITH CONSTANT AND VARIABLE AMPLITUDE LOADS

B - EXPERIMENTAL OBSERVATION OF CRACK GROWTH IN STIFFENED COMPONENTS UNDER VARIABLE LOADS

C - EVALUATION OF THE RELIABILITY OF THE MODELS FOR CRACK GROWTH IN AEROSPACE STRUCTURES

D - FINITE ELEMENTS PROCEDURES BASED ON LEFM TO EVALUATE K IN SIGNIFICANT GEOMETRIES AND STRESS FIELDS

E - EXPERIMENTAL MEASUREMENT OF K ALONG THE CRACK FRONT IN SPECIFIED TEST CASES

F - COLLECTION OF RESULTS ABOUT K ALONG DIFFERENT EVOLVING CRACK FRONTS, IN TYPICAL GEOMETRIES AND STRESS FIELDS

G - SPECIFICATION OF RELIABLE PROCEDURES FOR THE EVOLUTION OF A CRACK FRONT IN TYPICAL GEOMETRIES AND STRESS FIELDS

H - DEVELOPMENT AND EVALUATION OF COMPUTATIONAL PROCEDURES FOR THE DYNAMIC RESPONSE OF STRUCTURAL COMPONENTS UNDER RANDOM EXCITATION

I - EXPERIMENTS ON DYNAMIC RESPONSE OF TYPICAL STRUCTURAL COMPONENTS WITH SINUSOIDAL AND RANDOM EXCITATION

L - SPECIFICATION OF RELIABLE METHODS FOR THE EVALUATION OF DYNAMIC RESPONSE

M - EVALUATION OF THE RELIABILITY OF DIFFERENT NDI TECHNIQUES

N - SPECIFICATION OF THE SIZE OF INITIAL DEFECTS DEPENDING ON NDI METHODS AND STRUCTURE CHARACTERISTICS

O - DEVELOPMENT OF NEW MODELS FOR DUCTILE FRACTURE TOUGHNESS

P - EVALUATION OF THE RELIABILITY OF THE MODELS FOR EVALUATING RESIDUAL STRENGHT OF CRACKED AEROSPACE MATERIALS

Q - EXPERIMENTAL MEASUREMENT OF THE TOUGHNESS OF TYPICAL AEROSPACE MATERIALS, ALSO IN LARGE DUCTILITY SITUATIONS

R - COLLECTION OF RELIABLE DATA ON FRACTURE TOUGHNESS OF AEROSPACE MATERIALS ALSO FOR LARGE DUCTILITY SITUATIONS

S - DEVELOPMENT OF DESIGN PROCEDURES FOR MINIMUM WEIGHT STRUCTURAL ELEMENTS WITH SPECIFIED SAFE CRACK GROWTH LIFE

T - SPECIFICATION OF RELIABLE PROCEDURES FOR EVALUATING THE SAFE CRACK GROWTH LIFE OF AEROSPACE STRUCTURES IN TYPICAL SITUATIONS

U - SPECIFICATION OF RELIABLE PROCEDURES FOR EVALUATING THE RESIDUAL STRENGHT OF AEROSPACE STRUCTURES

V - PRODUCTION OF THE MANUAL: FRACTURE MECHANICS METHODS IN THE DESIGN OF AEROSPACE STRUCTURES

Z - DEVELOPMENT OF A COMPUTER PROGRAM FOR THE EVALUATION OF SAFETY AND DURABILITY OF AEROSPACE STRUCTURES CONTAINING POSSIBLE CRACKS AND FLAWS

Fig. 11 - Main items of cooperative research on Fracture Mechanics in the design of aerospace vehicles.

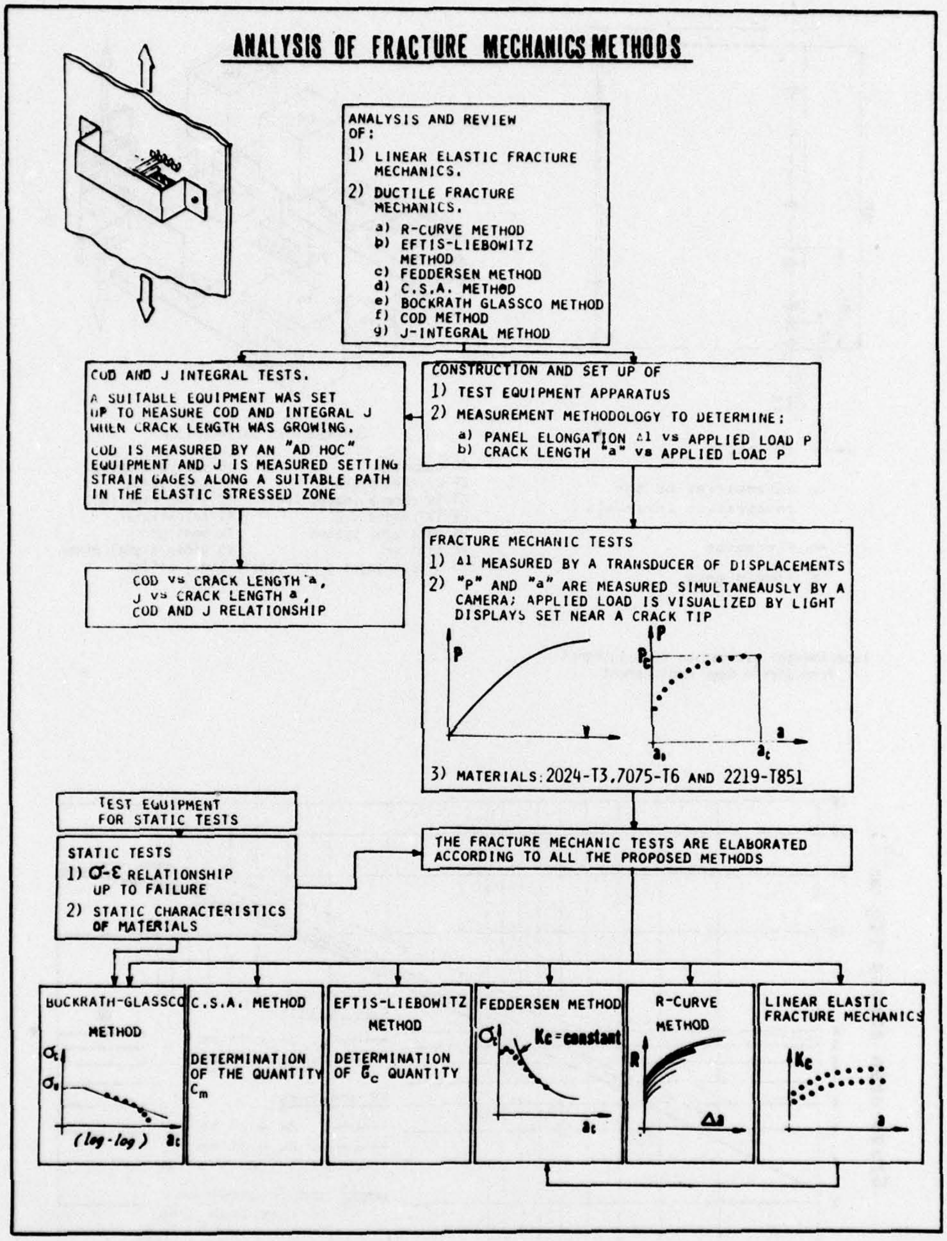


Fig. 12 - Outline of an approach for the critical evaluation of different Fracture Mechanics methods.

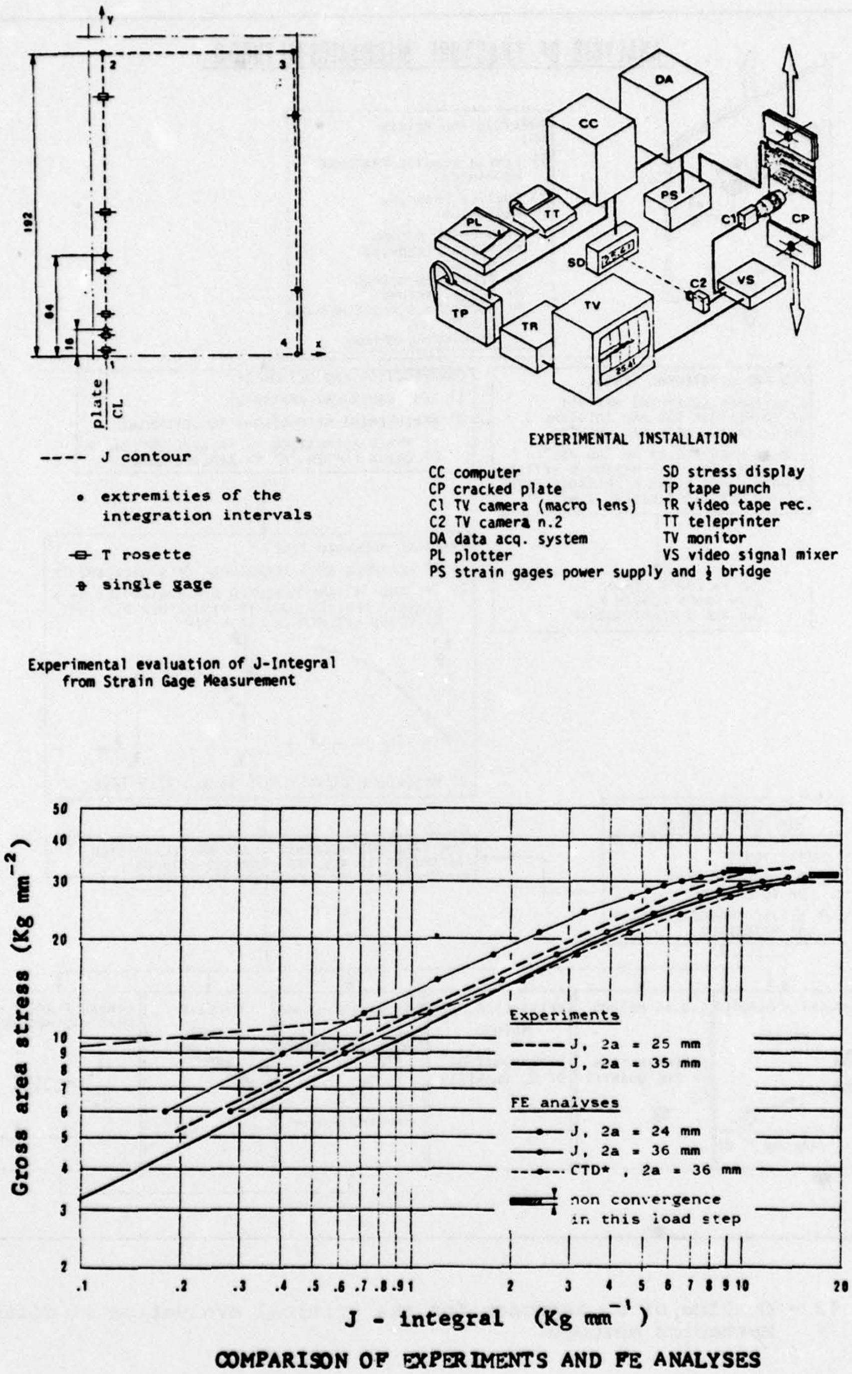


Fig. 13 - Experimental evaluation of models for ductile fracture.

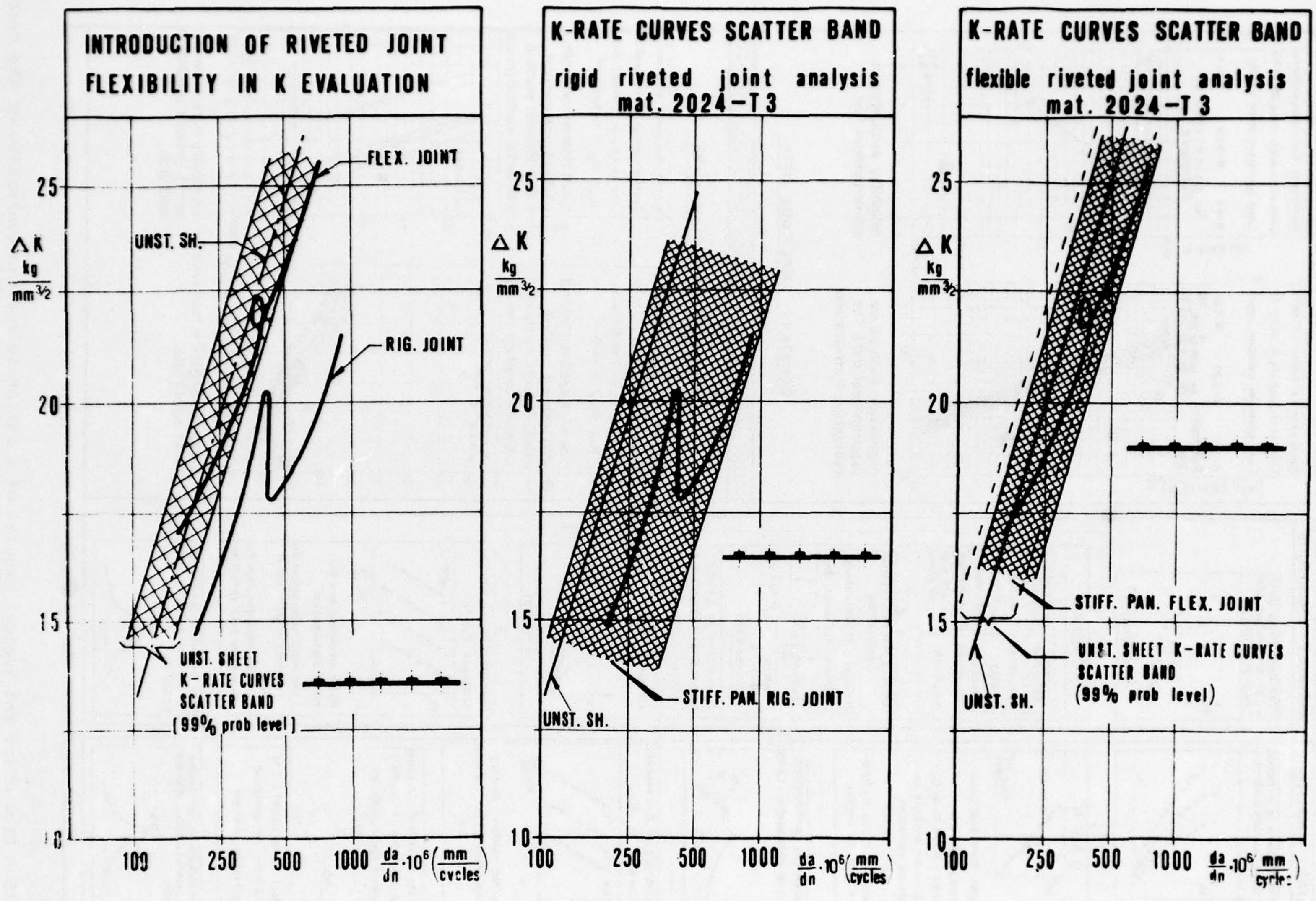


Fig. 14 - Researches on the fatigue crack propagation in riveted stiffened structures. Typical results on the influence of the joint flexibility.

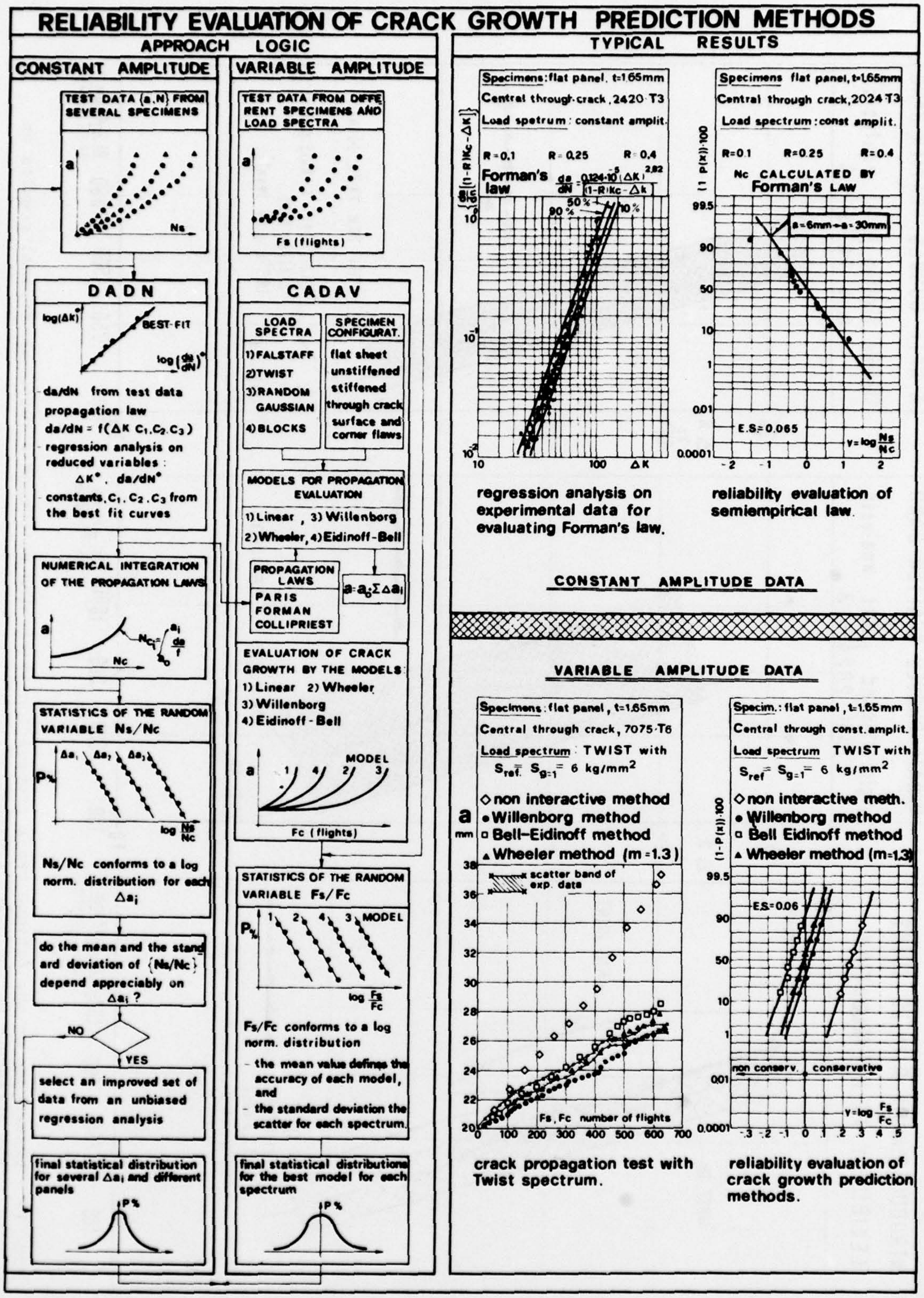


Fig. 15 - Flow chart and typical results of a rationale for the evaluation of the crack growth prediction methods.

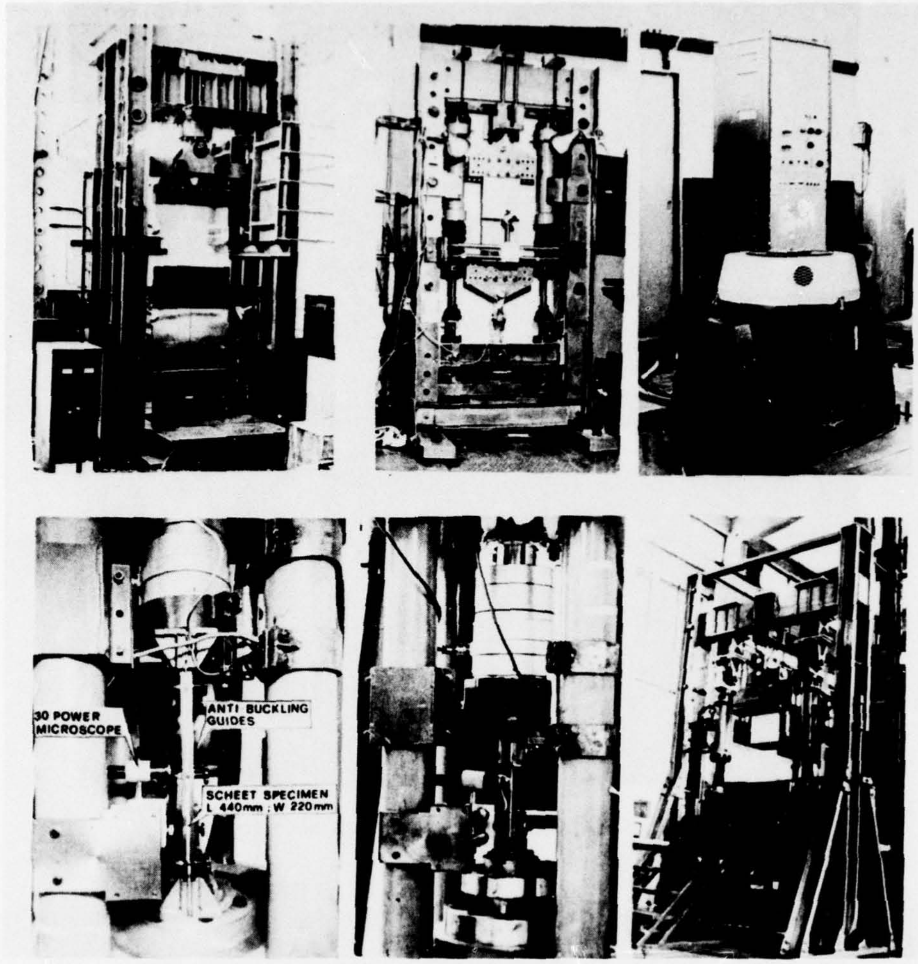


Fig. 16 - Facilities for fatigue and fracture mechanics tests at the University of Pisa, Institute of Aeronautics.

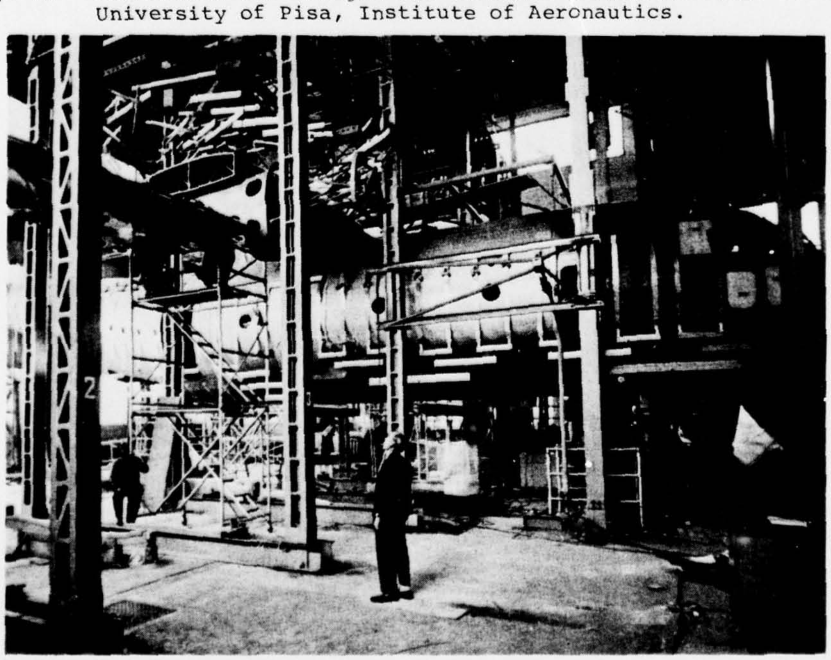


Fig. 17 - Fatigue Test of G. 222 Aircraft.

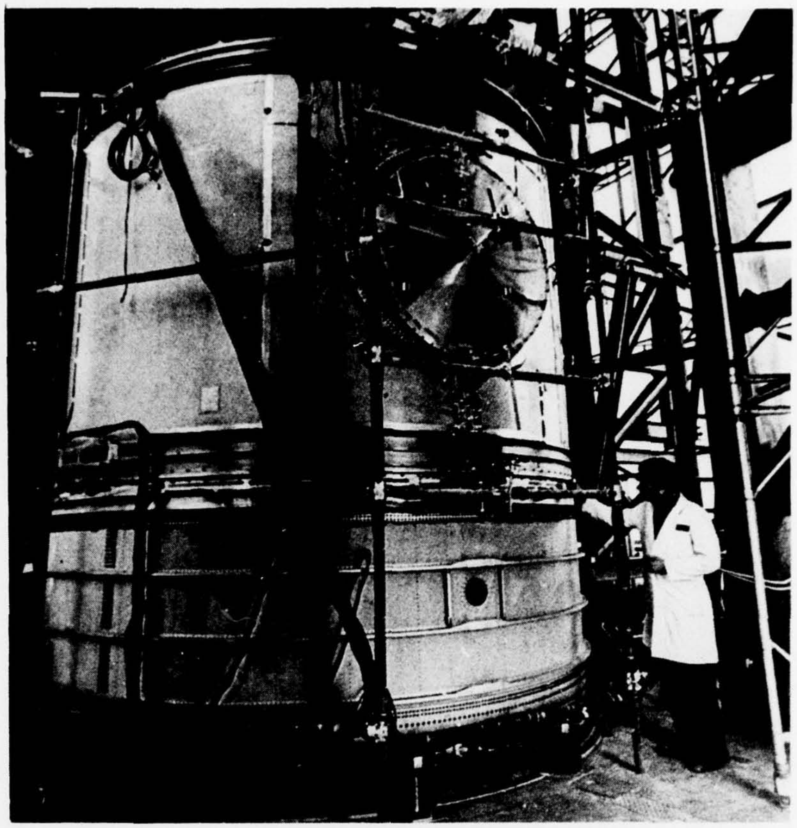


Fig. 18 - Static and fatigue test of Spacelab structure.

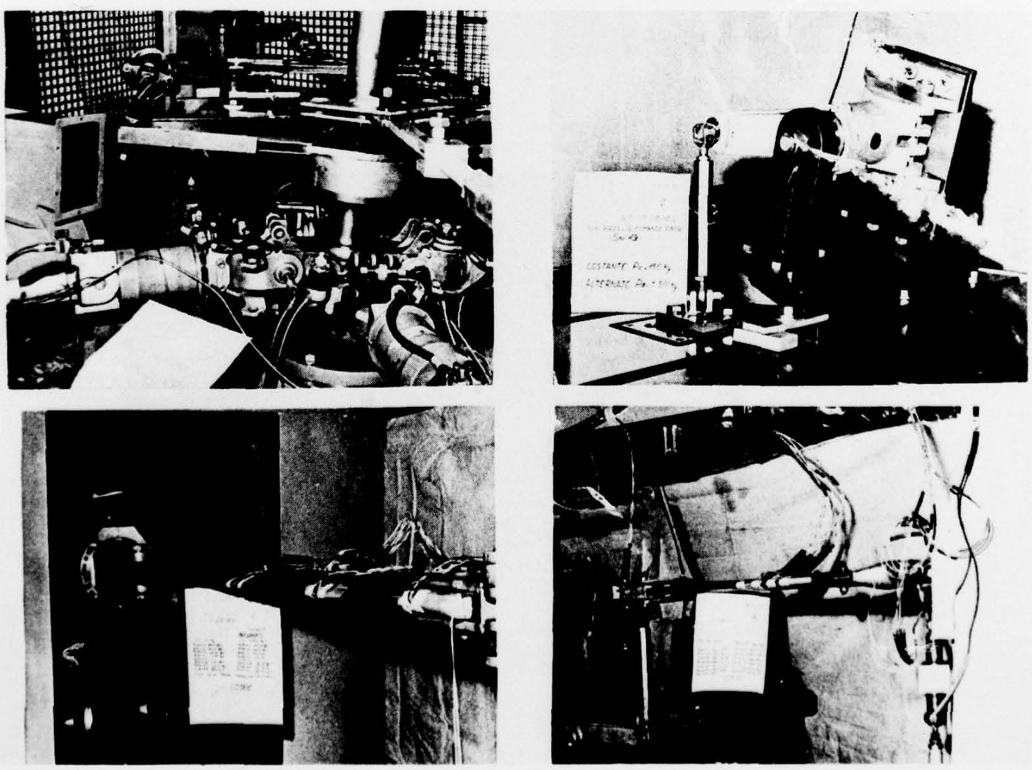


Fig. 19 - Typical fatigue tests of helicopter dynamic components at Agusta fatigue laboratory.

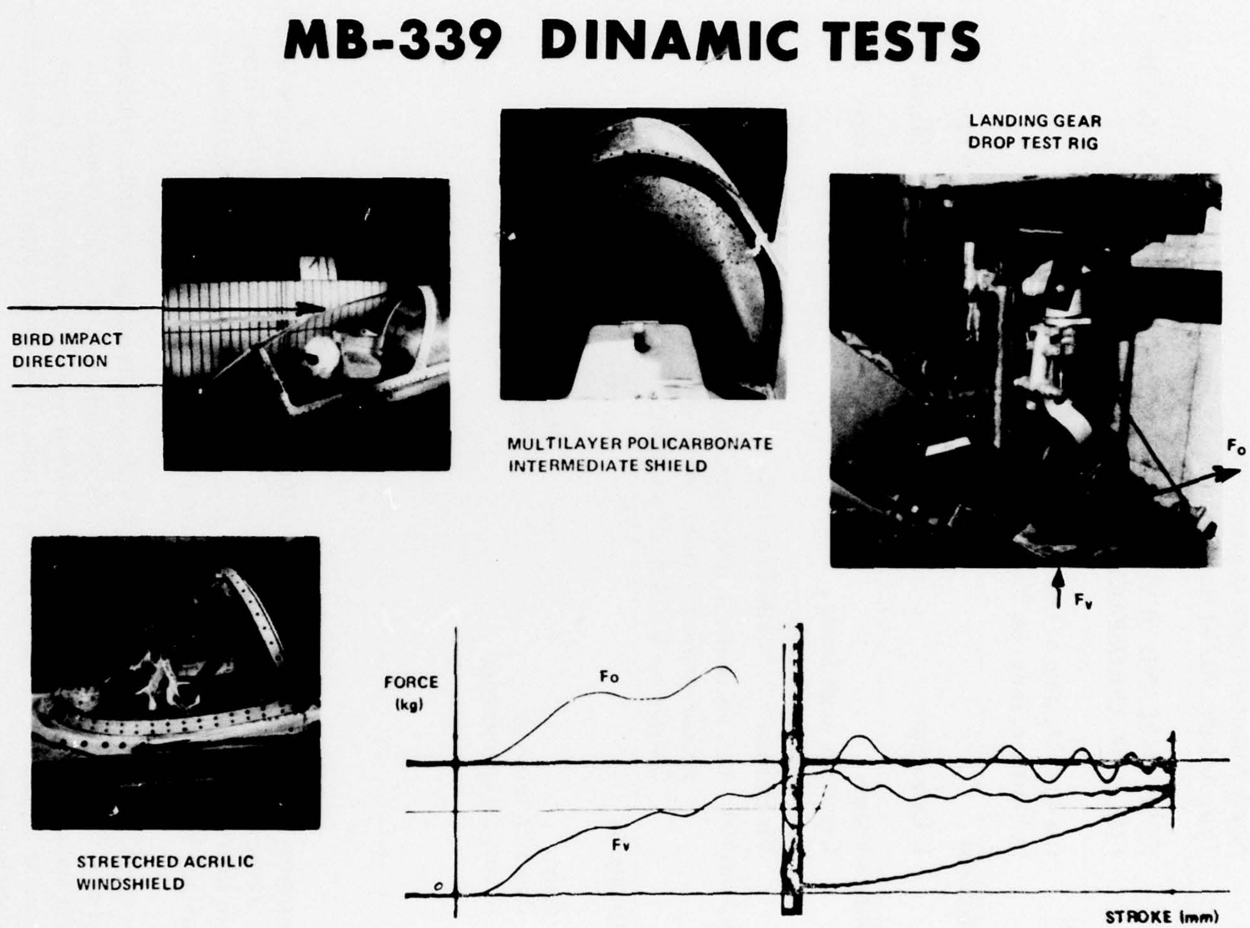


Fig. 20 - Aeronautica Macchi particular dinamic testing facilities.

REPORT DOCUMENTATION PAGE

1. Recipient's Reference	2. Originator's Reference	3. Further Reference	4. Security Classification of Document
	AGARD-R-675	ISBN 92-835-1315-0	UNCLASSIFIED

5. Originator Advisory Group for Aerospace Research and Development
North Atlantic Treaty Organization
7 rue Ancelle, 92200 Neuilly sur Seine, France

6. Title
RESEARCH AND DEVELOPMENT ACTIVITIES IN ITALY IN THE FIELD OF AEROSPACE STRUCTURES AND MATERIALS

7. Presented at
the 47th Meeting of the Structures and Materials Panel in Florence, Italy, on 25 September 1978.

8. Author(s)/Editor(s)	9. Date
L.Lazzarino	March 1979

10. Author's/Editor's Address	11. Pages
Universita degli Studi Facolta di Ingegneria Via Diotisalvi 2, 56100 Pisa, Italie	26

12. Distribution Statement This document is distributed in accordance with AGARD policies and regulations, which are outlined on the Outside Back Covers of all AGARD publications.

13. Keywords/Descriptors

Italy
Research projects
Aerospace engineering
Materials
Structural engineering

14. Abstract

After a summary of the main programs of the Italian aerospace industries, a review is performed of Research and Development activities, prevalently aimed at supporting these programs in the field of aerospace materials and structures; also, autonomous research work developed by some Italian Universities in this field is indicated.

This review considers the activities concerned with metallic and non metallic aerospace materials, the fields of stress analysis, vibrations and aeroelasticity, fatigue and crack propagation and particularly interesting development work aimed at resolving design problems and at facilitating the introduction of new technologies. Also, the main facilities developed are indicated.

Technical Address given at the 47th Meeting of the Structures and Materials Panel in Florence, Italy on 25 September 1978.

AGARD Report No.675	AGARD-R-675
Advisory Group for Aerospace Research and Development, NATO RESEARCH AND DEVELOPMENT ACTIVITIES IN ITALY IN THE FIELD OF AEROSPACE STRUCTURES AND MATERIALS by L.Lazzarino Published March 1979 26 pages After a summary of the main programs of the Italian aerospace industries, a review is performed of Research and Development activities, prevalently aimed at supporting these programs in the field of aerospace materials and structures; also, autonomous research work developed by some Italian Universities in this field is indicated. P.T.O.	Italy Research projects Aerospace engineering Materials Structural engineering

AGARD Report No.675	AGARD-R-675
Advisory Group for Aerospace Research and Development, NATO RESEARCH AND DEVELOPMENT ACTIVITIES IN ITALY IN THE FIELD OF AEROSPACE STRUCTURES AND MATERIALS by L.Lazzarino Published March 1979 26 pages After a summary of the main programs of the Italian aerospace industries, a review is performed of Research and Development activities, prevalently aimed at supporting these programs in the field of aerospace materials and structures; also, autonomous research work developed by some Italian Universities in this field is indicated. P.T.O.	Italy Research projects Aerospace engineering Materials Structural engineering

AGARD Report No.675	AGARD-R-675
Advisory Group for Aerospace Research and Development, NATO RESEARCH AND DEVELOPMENT ACTIVITIES IN ITALY IN THE FIELD OF AEROSPACE STRUCTURES AND MATERIALS by L.Lazzarino Published March 1979 26 pages After a summary of the main programs of the Italian aerospace industries, a review is performed of Research and Development activities, prevalently aimed at supporting these programs in the field of aerospace materials and structures; also, autonomous research work developed by some Italian Universities in this field is indicated. P.T.O.	Italy Research projects Aerospace engineering Materials Structural engineering

AGARD Report No.675	AGARD-R-675
Advisory Group for Aerospace Research and Development, NATO RESEARCH AND DEVELOPMENT ACTIVITIES IN ITALY IN THE FIELD OF AEROSPACE STRUCTURES AND MATERIALS by L.Lazzarino Published March 1979 26 pages After a summary of the main programs of the Italian aerospace industries, a review is performed of Research and Development activities, prevalently aimed at supporting these programs in the field of aerospace materials and structures; also, autonomous research work developed by some Italian Universities in this field is indicated. P.T.O.	Italy Research projects Aerospace engineering Materials Structural engineering

This review considers the activities concerned with metallic and non metallic aerospace materials, the fields of stress analysis, vibrations and aeroelasticity, fatigue and crack propagation and particularly interesting development work aimed at resolving design problems and at facilitating the introduction of new technologies. Also, the main facilities developed are indicated.

Technical Address given at the 47th Meeting of the Structures and Materials Panel in Florence, Italy on 25 September 1978.

ISBN 92-835-1315-0

This review considers the activities concerned with metallic and non metallic aerospace materials, the fields of stress analysis, vibrations and aeroelasticity, fatigue and crack propagation and particularly interesting development work aimed at resolving design problems and at facilitating the introduction of new technologies. Also, the main facilities developed are indicated.

Technical Address given at the 47th Meeting of the Structures and Materials Panel in Florence, Italy on 25 September 1978.

ISBN 92-835-1315-0

This review considers the activities concerned with metallic and non metallic aerospace materials, the fields of stress analysis, vibrations and aeroelasticity, fatigue and crack propagation and particularly interesting development work aimed at resolving design problems and at facilitating the introduction of new technologies. Also, the main facilities developed are indicated.

Technical Address given at the 47th Meeting of the Structures and Materials Panel in Florence, Italy on 25 September 1978.

ISBN 92-835-1315-0

This review considers the activities concerned with metallic and non metallic aerospace materials, the fields of stress analysis, vibrations and aeroelasticity, fatigue and crack propagation and particularly interesting development work aimed at resolving design problems and at facilitating the introduction of new technologies. Also, the main facilities developed are indicated.

Technical Address given at the 47th Meeting of the Structures and Materials Panel in Florence, Italy on 25 September 1978.

ISBN 92-835-1315-0